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OPERATING INSTRUCTIONS

FOR

Q-METERS

TYPE 160-A

BOONTON RADIO COMPANY
ROCKAWAY, NEW JERSEY
U. S. A.

5C/CP/4-63

Printed in U.S.A.

OPERATING INSTRUCTIONS

FOR

Q-METERS

TYPE 160-A

GENERAL ELECTRIC CO.
Instrumentation & Control
228 W. Florence Ave.
Inglewood, Calif. 90301

BOONTON RADIO COMPANY

Green Pond Road Rockaway, New Jersey

U.S.A.

5C/CP/4-63

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OPERATING INSTRUCTIONS FOR THE TYPE 160-A Q-METER

DESCRIPTION

The principal units of this instrument are (1) an R. F. oscillator, (2) a measuring circuit, (3) means for coupling the oscillator to the measuring circuit, and (4) a power supply.

The R. F. oscillator is continuously variable between 50 KC and .75 MC and supplies a calibrated voltage to the measuring circuit. The coupling unit consists of a shielded transmission line terminating in a thermocouple and .04 ohm non-inductive resistor. The thermocouple measures the current which passes through the .04 ohm resistor and its associated meter is calibrated as a multiplier of the circuit Q indicated by the Q voltmeter. The measuring circuit consists of the main and vernier Q tuning condensers and a VT Voltmeter. When a coil is connected to the external coil terminals and resonance established between the oscillator and the measuring circuit the Q voltmeter (in conjunction with the "Multiply Q By" meter) indicates the Q of the circuit.

SHIELDED CABLE AND JACK.

A shielded cable (and jack) is supplied to permit operation between 1KC and 50 KC with an external oscillator. The output of the external oscillator must be variable and capable of supplying a maximum current of 0.5 amperes into an impedance of approximately 1 ohm. When an external oscillator is employed, it is necessary to disconnect the internal oscillator of the Q-Meter. This is accomplished by rotating the oscillator range switch (Item 5, page 3), to a position intermediate between any of the frequency range settings. Under these conditions the Q-Meter may be used for Q measurements, i.e., the Q Voltmeter reads circuit Q directly when the "Multiply Q By" Meter reads x1.

CAUTION:

The current from the external oscillator passes through a thermocouple system within the Q-Meter, the output of which is indicated on the "Multiply Q By" Meter, and care must be taken that this current does not exceed a value of 0.5 amperes which corresponds to an indication of x1 on the "Multiply Q By" Meter.

The shielded cable should be disconnected when the Q-Meter is used for Q measurements above 50 KC, i.e., without the external oscillator.

The shielded cable (or an unshielded cable) may be used for obtaining the internal oscillator output voltage for general laboratory work. The jack into which the shielded cable is plugged is connected within the Q-Meter as shown in the schematic drawing on page 7, Item No. 48. The oscillator output voltage at the jack is approximately 0.5 volts maximum. (This EMF is produced by the current of 0.5 amperes through the resistance of the heater of the thermocouple which is approximately 1 ohm.) This voltage may be read on the Q voltmeter by connecting the conductor within the shielded cable to the "HI" coil or condenser terminal. This voltage is substantially constant with frequency and inversely proportional to the indication of the "Multiply Q By" Meter up to the frequency region of 1 MC. Above 1 MC this voltage rises above 0.5 volts (for x1 on the "Multiply Q By" Meter) due to resonant conditions of the transmission line and the shielded cable. In certain frequency regions above 10 MC this voltage will vary between wide limits unless the free end of the shielded cable is terminated with a suitable impedance.

INSTALLATION

GROUND CONNECTION.

A ground connection should be made to the binding post on the rear of the cabinet for protection of the Q voltmeter. In some instances it may be found helpful to connect a composition type 10,000-ohm 1/2 watt resistor in series with the ground lead, to eliminate resonance occurring in this lead.

POWER SUPPLY.

The power supply utilizes a dual-voltage transformer providing operation on either 115 or 230 volts, 50-60 cycles.

IMPORTANT:

Switch No. 30, page 3, must be set in the position corresponding to the voltage to be used. A lock is provided on this switch to prevent accidental changes in setting. (*)

(*) Type 160-A Q-Meters of early manufacture are not provided with this dual-voltage switch.

ON-OFF SWITCH.

When the ON-OFF switch (No. 22 page 3) is turned ON, the panel lamp near the switch should light and the oscillator output voltmeter should indicate some output. About a minute is required for the Q voltmeter tube to heat up; thus a short delay occurs before the Q voltmeter operates correctly.

PRECAUTION:

With earlier Type 160-A Q-Meters set the oscillator output control knob (No. 1, Page 3) to mid-position to avoid a possible overload of the thermocouple.

HI-LO SWITCH.

This switch is located on the underside of the cabinet and should be set to the HI position for power line voltages slightly above normal, and to the LO position for voltages below normal. Normal voltage is either 110 or 220 volts, depending upon the setting of switch No. 30 page 3.

OPERATION

The illustrations on page 3 will be helpful in identifying the various parts referred to in this and other sections. The figures in parentheses in the following description refer to the corresponding part on page 3.

CONTROLS.

There are four main controls, the oscillator range switch (5); the oscillator frequency control (3); the oscillator output voltage control (1); and the Q circuit tuning condensers, main (6) and vernier (10).

Q CIRCUIT TERMINALS.

Two terminals for coils (7) and two terminals for external condensers (8) are provided. The high potential and low potential terminals are indicated on the nameplate on the top of the Q-Meter.

***Caution:** The knurled tops of condenser terminals (8) should be finger tight when no external connections are made.*

SETTING THE OSCILLATOR FREQUENCY.

The desired frequency for a particular measurement may be obtained by selecting the range in which this frequency lies, by rotating the oscillator range switch (5) to this position and setting the oscillator tuning condenser (3) to the desired frequency.

The oscillator range switch dial (5) is engraved in eight frequency ranges, as follows:

50– 150	kilocycles	4.5–12.0	megacycles
150– 450	"	12.0–25.0	"
450–1500	"	25.0–50.0	"
1.5– 4.5	megacycles	50.0–75.0	"

The oscillator frequency dial (3) contains the calibrated scales corresponding to these same frequency ranges. The first three frequency ranges, which are calibrated in kilocycles, are engraved on the top half of this dial. The next four ranges, which are calibrated in megacycles, are engraved on the lower half of this dial. The eighth range, 50-75 mc, is engraved in RED on the top half of the dial.

ADJUSTING THE OSCILLATOR OUTPUT VOLTAGE.

The oscillator output voltage is indicated by the "Multiply Q By" meter. When the oscillator output is adjusted so that this meter reads x1 the Q voltmeter scale is to be read directly. For circuit Q's exceeding Q = 250 the oscillator output should be adjusted so

ILLUSTRATING THE IMPORTANT FEATURES IN THE OPERATION AND CONSTRUCTION OF THE TYPE 160-A Q-METER

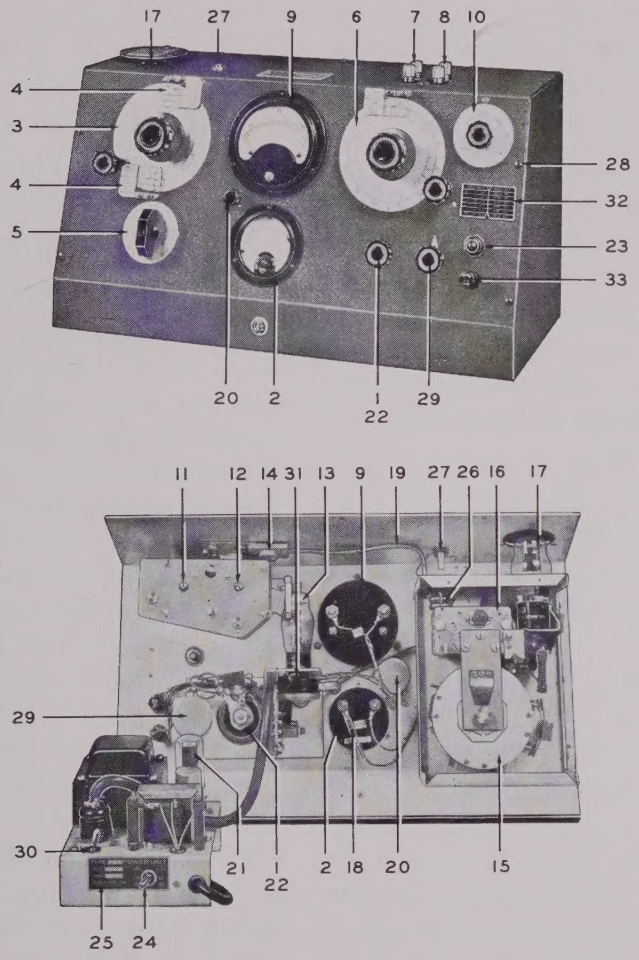

Fig. 1

DESCRIPTION OF PARTS

1 Oscillator Output Control.
2 Osc. Out. VM. (Mult. Q By Meter).
3 Oscillator Frequency Dial.
4 Oscillator Frequency Indicator.
5 Oscillator Range Switch.
6 Q Tuning Condenser Dial.
7 Coil Terminals.
8 Condenser Terminals
9 Q Voltmeter
10 Vernier Tuning Condenser Dial.
11 Vernier Tuning Condenser
12 Q Tuning Condenser.
13 Q Voltmeter Tube.
14 Thermocouple Unit.
15 Oscillator Range Switch Assembly.
16 Oscillator Tuning Condenser.
17 Oscillator Tube.
18 Thermocouple Calibrating Resistor.
19 Oscillator Output Cable.
20 VTVM Zero Adjust.
21 Rectifier Tube.
22 ON–OFF Switch.
23 Pilot Light.
24 HI–LO Switch.
25 Power Unit Nameplate.
26 Thermocouple Filter.
27 Jack.
28 Panel Securing Screws.
29 Oscillator Output Control, Vernier.
30 Dual-Voltage Switch (115-230 volts).
31 VTVM Calibration Control.
32 Frequency Reference Plate.
33 Fuse Holder.

that the "Multiply Q By" meter indicates a factor higher than x1, e.g., x1.1 or x1.2, etc. The Q voltmeter scale is then to be multiplied by this factor. For greatest accuracy the "Multiply Q By" meter should read as close to unity (i.e., x1) as is possible. The adjustment is made by means of the main control knob (1) and vernier control knob (29).

NOTE: In this method of indicating oscillator output voltage, the maximum oscillator output voltage to be employed exists when the "Multiply Q By" meter reads x1. For higher multiplying factors the oscillator output voltage is reduced, e.g., when the "Multiply Q By" meter is adjusted to read x2 the oscillator output voltage has been reduced to one half.

CAUTION: Care should be taken when changing the oscillator frequency to watch the oscillator output voltmeter and avoid overloading. This is a thermal meter system and excessive oscillator output may result in damage to the thermocouple.

ADJUSTING THE Q VOLTMETER.

The Q voltmeter (9) is adjusted to zero by means of the small knob directly below and to the left of the meter (see fig. 1).

For this adjustment a D.C. path between the two coil terminals must be provided, either by shorting the terminals with a jumper or connecting a coil to them. The Q circuit must be detuned from the oscillator frequency by rotating the Q tuning condenser through an appreciable range and observing that no change occurs in the Q voltmeter reading. The Q voltmeter should then be set to zero.

This adjustment should be made after the tubes have warmed up for about a minute and will then remain fairly constant. It is advisable, especially when accurate measurements with low Q circuits are being made, to check the zero setting of the meter occasionally by detuning the Q circuit.

The Q voltmeter should never be set to zero with the coil terminals open, since there is ordinarily an appreciable deflection of the meter due to the small grid current in the voltmeter tube with the coil terminals open. This deflection has no bearing on the accuracy of the meter as normally used to measure Q with a coil connected across the coil terminals.

PRECAUTION: Under certain circumstances extraneous voltages may be picked up by the exposed coil, from fields external to the Q-Meter. To determine if this is the case the oscillator should be definitely detuned from the circuit under measurement. The Q voltmeter should then read zero.

MEASUREMENT PROCEDURE – COILS.

A coil to be measured should be connected to the coil terminals (7)—page 3—provided on the Q-Meter, the oscillator frequency set to the desired frequency, and the coil resonated by means of the Q tuning condenser dial (6). Resonance is indicated by maximum deflection of the Q voltmeter (9). The Q voltmeter reading at resonance times the "Multiply Q By" factor indicates directly the Q of the measuring circuit. This is substantially the Q of the coil, except at the higher frequencies.

Since most coils in common use have a Q less than 250, it is advisable initially to set the oscillator output meter to the x1 position. If the Q of the test coil exceeds 250 the oscillator output voltage should be reduced, so that the "Multiply Q By" factor is increased.

The engineer will be able to estimate roughly the frequency at which a coil will resonate with a given tuning capacitance. Occasionally this may be difficult to estimate, particularly in the case of universal and multiple-section windings, in which case it becomes necessary to search for this resonance. The simplest method of doing this is to set the capacitance of the Q tuning condenser to about 100 or 200 $\mu\mu$f then to step the oscillator range-switch, sweeping each range with the oscillator condenser until resonance is indicated.

The oscillator output voltage is fairly uniform over the entire frequency range, except on the 50-75 mc range. Having obtained resonance, the oscillator output should be adjusted as above described.

The tuning capacitance required to resonate the coil may be read directly on the Q tuning condenser dial (6) in micro-microfarads. This capacitance is the total circuit capacitance of the measuring circuit in

the Q-Meter, including the voltmeter tube and terminals, but with nothing connected to the terminals.

This calibration obtains with the vernier condenser set at zero. With the vernier at some other position the total tuning capacitance is the sum of the readings of the main condenser dial and the vernier dial.

When leads or fixtures having appreciable capacitance are connected to the Q-Meter terminals and it is necessary to know the tuning capacitance accurately, the capacitance of these should be measured and added to the capacitance indicated on the dials.

MEASUREMENT PROCEDURE–OTHER COMPONENTS.

To measure components other than coils such as condensers, resistors, chokes, and insulating materials, it is necessary to provide a coil which will resonate to the frequency desired within the range of tuning capacitance of the Q-Meter (30 to 450 $\mu\mu$f) plus any additional capacitance of the components. This coil should be connected to the coil terminals of the Q-Meter and measurement of Q made as described above.

The measurement of such components requires two observations, one with the component disconnected and one with the component connected either in parallel with the Q circuit (to the condenser terminals (8)—page 3) or in series with the Q circuit. A series connection should be made in the coil circuit (between the coil and Q-Meter terminals) and provision made to maintain a continuous D.C. path through the coil and series component (by a resistor of not over 5 megohms shunting the component), if necessary.

Q, capacitance and frequency may be recorded for each observation which provides the necessary factors to calculate the quantity desired.

A more detailed description of the various measurements that may be made with the Q-Meter is given in the manual of RF measurements.

For many purposes comparison between similar components is as useful as measuring a specific factor, in which case it is unnecessary to make any calculations. The decrease in Q and change in tuning capacitance when the component is connected provide a rapid and accurate method of comparing a test component to a standard.

ACCURACY.

Q. The accuracy of the direct reading Q measurement is generally within 5% over the entire range of the Q-Meter except at the higher frequencies (above about 30 megacycles) where the accuracy may be somewhat less. In some cases at lower frequencies (with coils having a high distributed capacitance) the accuracy may be less. (See pages 2 to 3.)

Capacitance. The calibration of the Q tuning condenser is held to within plus or minus 1 $\mu\mu$f from 30 to 100 $\mu\mu$f and plus or minus 1% above 100 $\mu\mu$f. The dial calibration indicates the total circuit capacitance with the vernier set at zero, and with nothing connected to the Q-Meter terminals. The vernier condenser is accurate to 0.1 $\mu\mu$f.

Frequency. Accurate to about 1%. The average accuracy is generally better than 1%, especially near the low frequency end of each range.

COUPLING RESISTANCE.

In this instrument the oscillator output voltage is injected in the Q measuring circuit by means of a coupling resistance. This resistance unit is non-inductive and is of a very low order of resistance (0.04 ohm). In most cases this value of resistance is negligible, but the series resistance of resonant LC circuits may become very low at the higher frequencies, and the coupling resistance may then become an appreciable portion of the total circuit resistance and introduce an error.

This is unimportant in considerable design work where the main objective is to improve an existing coil or design the best component or circuit for a specific purpose, in which case the absolute Q is generally not wanted but a comparison between various components is highly desirable.

INTERNAL INDUCTANCE.

The internal inductance of the Q measuring circuit has been reduced to a low value by using short connections between the output binding posts and the Q tuning condenser. This inductance is less than .015 μhy at the binding posts.

MAINTENANCE

PARTS REQUIRING REPLACEMENT.

The only parts in the instrument that should require replacement are the dial lamp and the tubes consisting of:

1 Type 105-A for use in the vacuum tube voltmeter.*

1 Type 102-A tube for use in the oscillator (tested type 45).

1 Type 5W4 or 5Y3GT rectifier tube.

1 Mazda 47, 6 volt Panel Indicator Lamp.

The type 105-A tube is specially manufactured and calibrated for Q-Meter use. The type 102-A tube is a standard type 45 tube, tested for high frequency operation. Replacement tubes of these two types should be procured from Boonton Radio Corporation, Boonton, New Jersey, for best performance in the Q-Meter.

*Type 105-A is also a replacement for types 101-A and 101-B tubes no longer available used in early type 160-A Q-Meters.

DEFECTIVE TUBES.

Normally the tubes used in the Q-Meter have a long useful life, although occasionally a defective tube may be encountered and must be replaced.

A defective type 102-A tube will usually be indicated if it is impossible to obtain full oscillator output voltage when the "HI-LO" voltage adjustment switch has been properly set. (See page **2.**) It is also advisable to check the type 5W4 or 5Y3GT rectifier tube.

The type 105-A tube (vacuum tube voltmeter) has been carefully selected to meet the following requirements (a) high input A.C. resistance (10 megohms minimum at 1000 kcs); (b) low grid current (0.05 microamperes) at normal operating voltages; (c) uniform plate current under normal operating voltages.

The vacuum tube voltmeter tube should be replaced if the Q voltmeter goes off scale when both high potential Q circuit terminals are disconnected from external circuits. (This condition does not indicate that the calibration of the Q voltmeter is in error but is due merely to grid current.) The calibration of the tube may be checked by measuring a standard coil of known Q.

The calibration of the Q voltmeter may be checked against a standard 60 cycle A.C. voltmeter by applying known voltages ranging from about 0.5 volt to 5.0 volts at the condenser terminals of the Q-Meter. Referring to the schematic circuit diagram (see page **7**), the cathode-ground bypass condenser (18) must be temporarily increased to 8 μf for the 60 cycle calibration. The basing diagram for the type 105-A tube is the same as type 2A6, i.e., the cathode connects to pin No. 5.

REPLACEMENT OF TUBES.

The lower illustration on page **3** shows the type 105-A Q-voltmeter tube (13), the type 102-A oscillator tube (17), and the type 5W4 or 5Y3GT rectifier tube (21) in position. (NOTE: the shielding box cover over the oscillator range switch and coil assembly (15) has been removed in this illustration).

The oscillator tube may be removed after removal of the vent lid from the top of the cabinet. The Q voltmeter tube and rectifier tube are accessible upon removal of the front panel from the cabinet (remove nine securing screws from sides and top of panel—see item 28, page **3**).

CAUTION: The instrument should be disconnected from the power line before the panel is removed to avoid possibility of contact with the 250 "B" voltage or power line terminals within the instrument.

The panel lamp is accessible from the front of the panel.

ALIGNMENT OF DIALS.

If the dials or the indicators have been removed they may be correctly replaced in the following manner:

Oscillator. Turn the oscillator tuning condenser to the full maximum capacitance (low frequency) position, turn the dial until the zero line on the dial scale coincides with the vertical line of the top indicator, secure the dial to the shaft by means of the set screws and then adjust the top indicator more carefully to exact coincidence. The dial should be positioned on the shaft of the condenser as to be close to the indicator to avoid parallax but should not scrape. The lower indicator should then be carefully adjusted to exact coincidence with the line at the 100 scale position of the dial.

Main Q Tuning Condenser. The procedure outlined above should be followed and the condenser

SCHEMATIC CIRCUIT DIAGRAM OF TYPE 160-A Q-METER

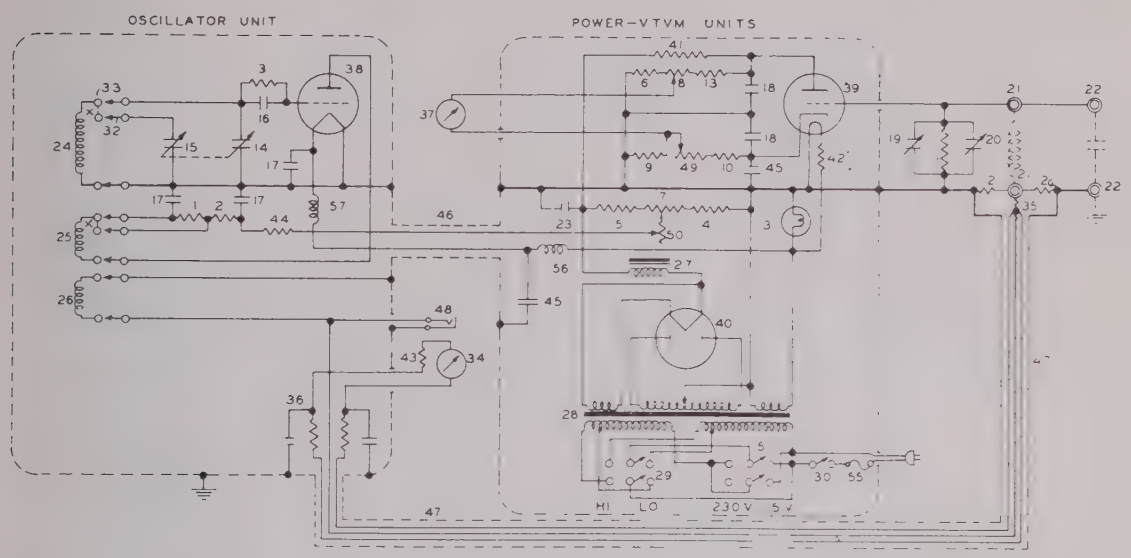

Fig. 2

CIRCUIT CONSTANTS AND DESCRIPTION OF PARTS

1	Fixed resistor	1,000 ohms.
2	Fixed resistor	200 ohms.
3	Fixed resistor	40,000 ohms.
4	Fixed resistor	2,500 ohms.
5	Fixed resistor	750 ohms.
6	Fixed resistor	200 ohms.
7	Potentiometer	8,000 ohms.
8	Potentiometer	200 ohms.
9	Fixed resistor	24,000 ohms.
10	Fixed resistor (1%)	24,000 ohms.
11	Fixed resistor	100 megohms.
12	12a (one unit) Fixed res.	.04 ohms.
13	Fixed resistor	54,000 ohms.
14	Osc. Tuning Condenser	(small).
15	Osc. Tuning Condenser	(large).
16	Fixed Condenser	.0001 μf.
17	Fixed Condenser	.003 μf.
18	Fixed Condenser	.0051 μf.
19	Q Tuning Condenser	(Main).
20	Q Tuning Condenser	(Vernier).
21	Terminals for test coils.	
22	Terminals for test condensers	
23	Power filter condensers	15 μf.
24	Oscillator grid coil.	
25	Oscillator plate coil.	
26	Oscilator coupling coil.	
27	Power filter choke	
28	Power Transformer	
29	"HI-LO" switch.	
30	Line "ON"-"OFF" switch.	
31	Panel Lamp (Mazda 47, 6 volts).	
32	Oscillator range switch contacts.	
33	Oscillator range switch (see note).	
34	Oscillator output voltmeter.	
35	Oscillator output thermocouple.	
36	R.F. filter for osc. voltmeter.	
37	Q Voltmeter.	
38	Oscillator tube (type 102-A).	
39	Q voltmeter tube (type 105-A).	
40	Rectifier Tube (type 5W4 or 5Y3GT)	
41	Fixed resistor	1,000 ohms.
42	Fixed resistor	0.3 ohms.
43	Thermocouple calibrating resistor.	
44	Fixed resistor	100 ohms
45	Fixed condenser	0.1 μf.
46	Shielded Cable.	
47	Shielded Cable.	
48	Jack.	
49	Potentiometer	3,000 ohms.
50	Potentiometer	1,000 ohms.
51	Dual-Voltage Switch (115-230 volts).	
55	Fuse	1-1 2 amp.
56	RF Choke.	
57	RF Choke.	

NOTE: On some oscillator ranges the connections shown in dash lines are made.

turned to the maximum capacitance position so that the line which is beyond the capacitance calibration is coincident with the line on the indicator.

Oscillator Range Switch. This is keyed to the shaft in such a way that the only error possible is a 180 degree error and this may be readily avoided.

POWER UNIT VOLTAGES.

Referring to the schematic circuit diagram, page 27, the following voltages should obtain at the power unit.

With a line voltage of 115 volts, 60 cycles and line switch set on "HI" the A.C. voltage for the heaters should be 2.5 volts. The "B" voltage across the filter condenser (23) should be 260 volts.

THERMOCOUPLE.

If the thermocouple should be damaged or burned out it is highly advisable to return the Q-Meter to Boonton Radio Corporation, Boonton, New Jersey, for replacement of the thermocouple unit to insure highest accuracy of calibration. If this should be impossible, replacement thermocouple units will be supplied, calibrated to match any one Q-Meter. *It is necessary to state the type number and serial number of the Q-Meter in ordering a replacement thermocouple unit. Thermocouple replacement instructions and a mounting for a spare thermocouple unit are provided within the Q-Meter cabinet.*

METERS.

If a "Multiply Q By" meter should be damaged or defective it should be returned *together with the small calibrating resistor* connected to one side of the meter (see 18, page **3) for repair.**

The serial number of the Q-Meter must always be stated when returning any meters for repair, or ordering replacements.

IF THE Q-METER SHOULD BECOME DEFECTIVE IN OPERATION DUE TO ANY CAUSE OTHER THAN TUBE FAILURE, IT IS ADVISABLE TO RETURN IT TO BOONTON RADIO CORPORATION, BOONTON, NEW JERSEY, FOR COMPLETE INSPECTION AND REPAIR.

SPECIFICATIONS

OSCILLATOR FREQUENCY RANGE: Continuously variable from 50 kilocycles to 75 megacycles in eight, self contained, ranges. (In conjunction with an external oscillator the frequency range of the type 160-A Q-Meter may be extended from 50 kilocycles to 1 kilocycle for coil measurements.)

OSCILLATOR FREQUENCY ACCURACY: Generally better than ±1%, except the 50-75 megacycle range which is approximately ±3%.

RANGE OF Q MEASUREMENTS: The Q voltmeter is calibrated directly in Q, 20-250. The "Multiply Q By" meter, which measures the oscillator voltage injected in the Q measuring circuit, is calibrated in tenths from x1 to x2, and also at x2.5. The reading of the Q voltmeter scale is to be multiplied by the setting of the "Multiply Q By" meter. Hence, the total range of circuit Q measurements is from 20-625. The Q's of condensers, dielectrics, etc., which may be as high as 5,000, are measured by placing these in parallel with the measuring circuit.

ACCURACY OF Q MEASUREMENTS: The accuracy of the direct reading measurement of circuit Q (for Q voltmeter readings between Q = 50 and Q = 250) is approximately 5% for all frequencies up to the region of 30 megacycles, and decreases with increasing frequency. Correction may be made for the error above 30 megacycles as it is principally a frequency effect. The accuracy of the measurement of condensers, dielectrics, etc., is generally better than 10% for Q's between 20 and 5,000, up to about 30 megacycles.

CAPACITANCE CALIBRATION RANGE: Main tuning condenser 30-450 $\mu\mu$f, calibrated in 1 $\mu\mu$f divisions from 30 to 100 $\mu\mu$f, and in 5 $\mu\mu$f divisions from 100 to 450 $\mu\mu$f. Vernier condenser, plus 3 $\mu\mu$f, zero, minus 3 $\mu\mu$f, calibrated in 0.1 $\mu\mu$f divisions.

ACCURACY OF CAPACITANCE CALIBRATION: Main tuning condenser, generally better than 1% or 1 $\mu\mu$f, whichever is the greater. Vernier tuning condenser ±0.1 $\mu\mu$f. The internal inductance of the tuning condenser at the binding posts is approximately .015 μhy.

VOLTMETER: The Q voltmeter is also calibrated in volts. A specially calibrated tube, type BRC 105-A tube, is used. Replacements may be made without recalibration.

POWER SUPPLY: A self-contained dual-voltage transformer with change-over switch provides operation on either 105-120 volts, 50-60 cycles ,or 210-240 volts, 50-60 cycles. Power consumption 50 watts.

TUBES: The Q-Meter is supplied complete with tubes which are (a) one type BRC 102-A tube, (b) one type BRC 105-A tube, (c) one type 5W4 or 5Y3GT tube, and (d) Mazda 47, 6 volt, panel lamp.

DIMENSIONS: Height 12.5", length 20", depth 8.5".

INSTRUCTION BOOK: Manual of r. f. measurements accompanies instrument.

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1002165